Advanced Accelerator Applications (AAA)

Spoke-Cavity ED&D Power Coupler Design Review

August 2, 2001

RF Design of the ED&D Power Coupler

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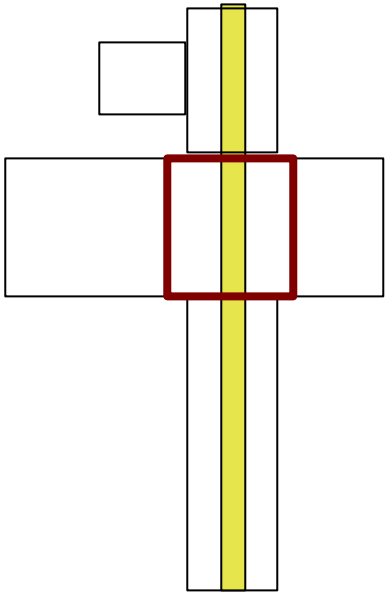
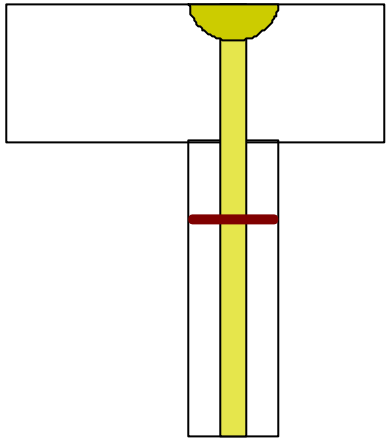
Coupler Geometries Considered

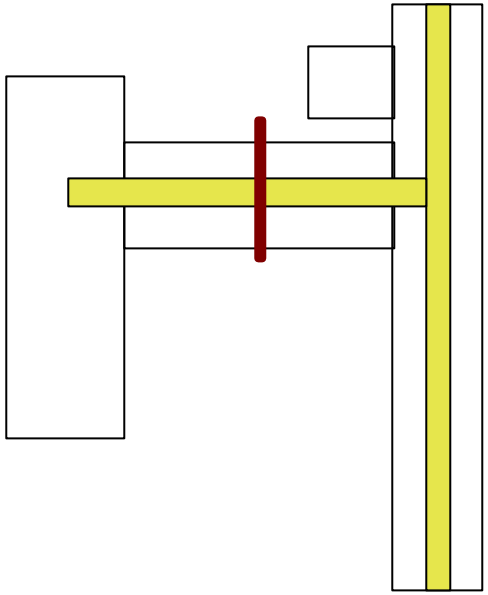


Tristan-type
- Free orientation
- Proven w/ beam at 225 kW
- Good vacuum@ window
- Small footprint
- Low cost



KEK-type
- Up or down orientation
- Proven w/ beam at 380 kW
- Small footprint

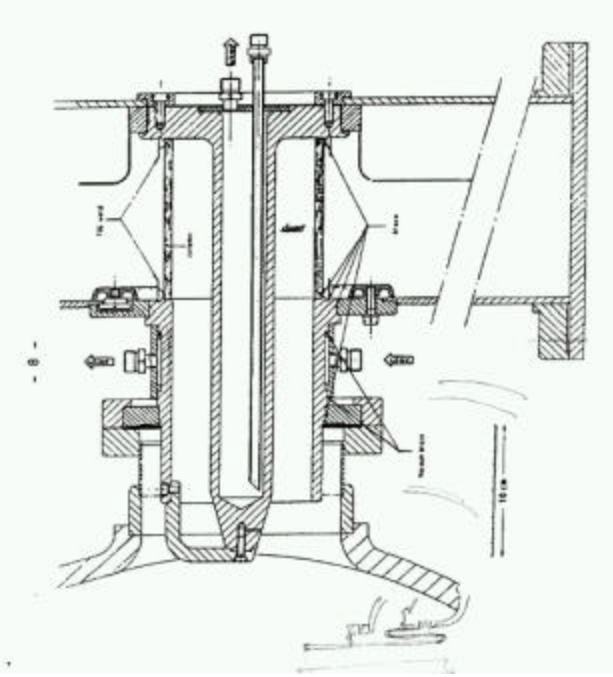
- Doorknobs seem to be more prone to MP
- Higher cost



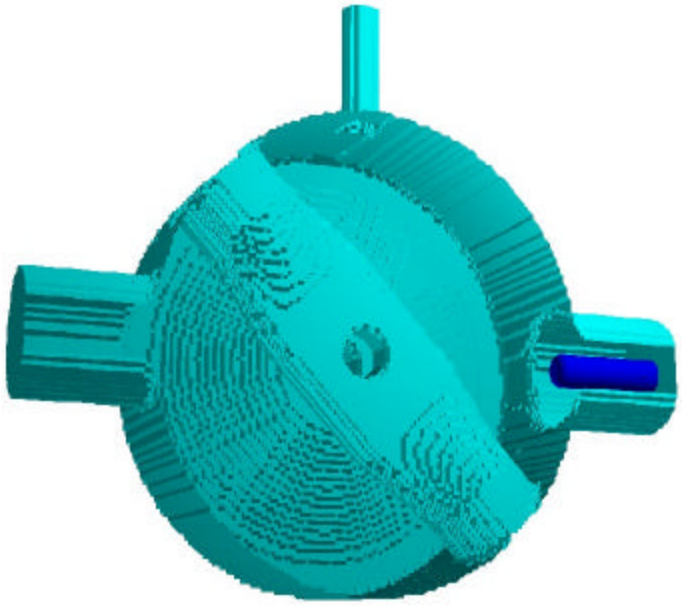
APT-type
- Free orientation
- Proven w/o beam at 1 MW
- Good vacuum @ window
- Local experience

- Big footprint
- High cost

Electric vs. Magnetic Coupling



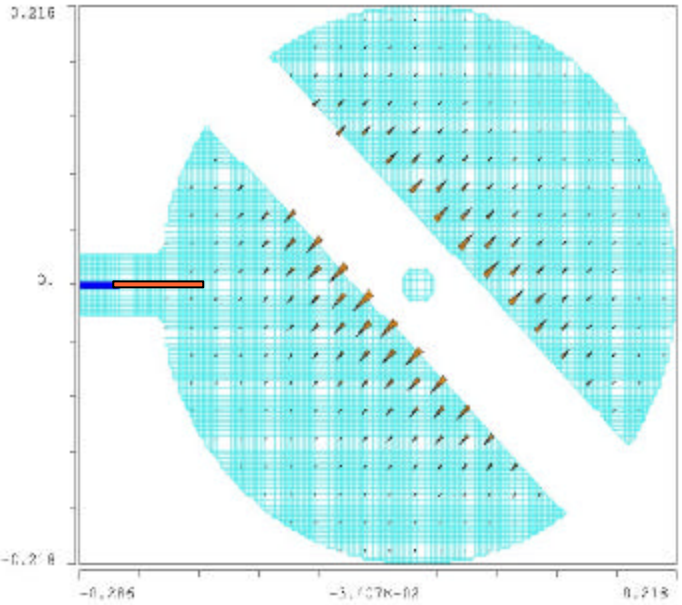
Magnetic loop coupling is complex: e.g. thermal management for high tranmitted power.

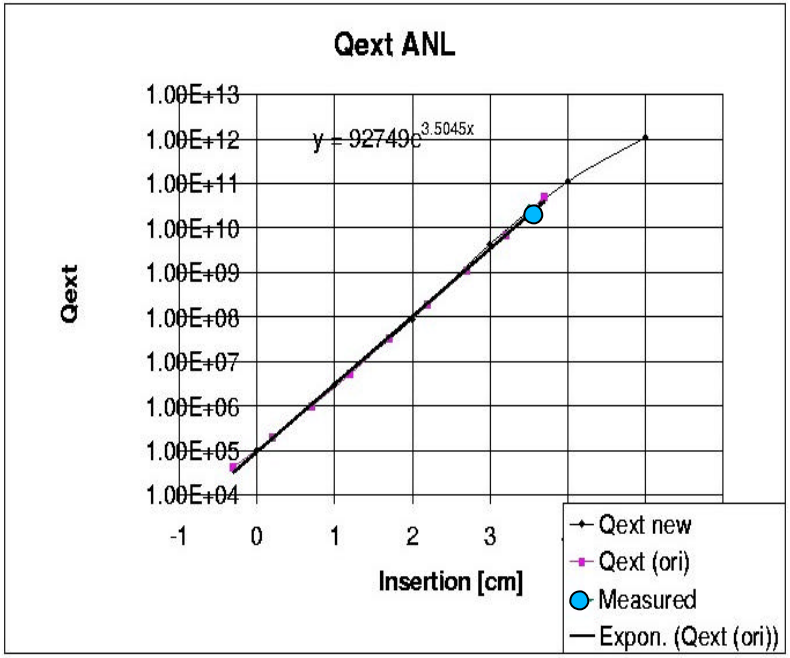


During a spoke resonator review it was proposed to investigate the possibility of an electric coaxial coupler.

Electric Coupling Verification

ANL β=0.3 Cavity





Q_{ext} vs tip position is plotted here for 2 simulation procedures. Also a fitting curve and the fitting function are given. The only datapoint plotted is the average measured Q_{ext} for the pickup probe. The difference between the measured and calculated value can be explained by a tip position inaccuracy of 0.5 mm.

Coax Size/Impedance Choice

1. Criterium: Multipacting vs. Beam Power:

Single Point MP levels compared between CERN and derived ADTF scenarios

Order	CERN	ED&D-103	ED&D-100	APT-Geo
	352 MHz 75 Ω	350 MHz 75 Ω	350 MHz 75 Ω	350 MHz 50 Ω
7	48 kW	47 kW	42 kW	28 kW
6	52 kW	51 kW	45 kW	30 kW
5	88 kW	86 kW	76 kW	51 kW
4	176 kW	172 kW	153 kW	102 kW
3	234 kW	229 kW	204 kW	136 kW
2	448 kW	438 kW	389 kW	259 kW
1	640 kW	626 kW	556 kW	371 kW

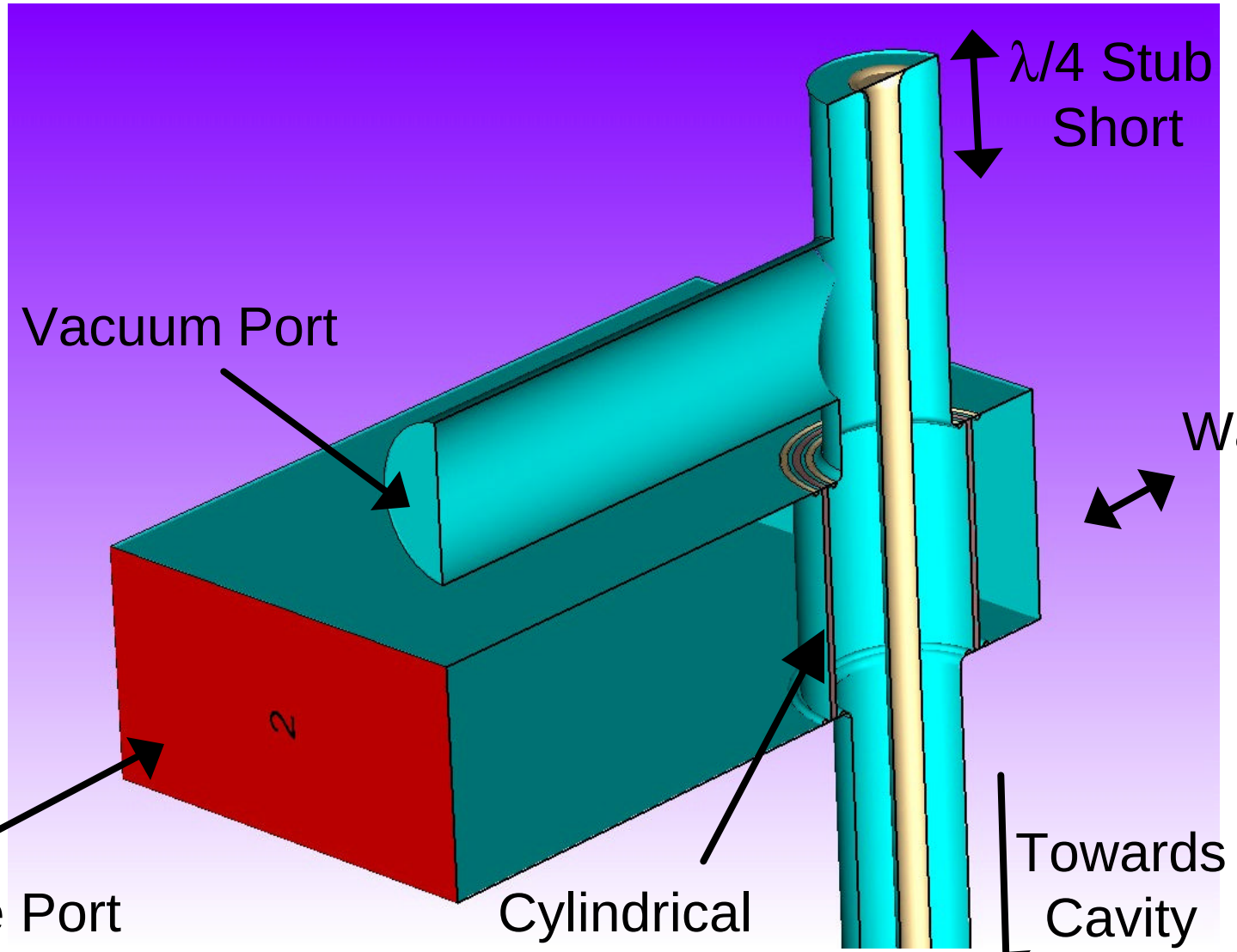
Average Input Power Levels for the Spoke Resonators (ϕ=–30°)

	13.3 mA	100 mA
β=0.175	6 kW	43 kW
β=0.34	19.5 kW	144 kW
for E_0T = 5 MV/m		

	13.3 mA	100 mA
β=0.175	8.5 kW	63.6 kW
β=0.34	28.2 kW	211.8 kW
for E_0T = 7.5 MV/m		

2. Cavity Size: The β=0.175 cavity is limited to coax sizes around approximately 100 mm

Optimization w/ HFSS/MAFIA/MWS



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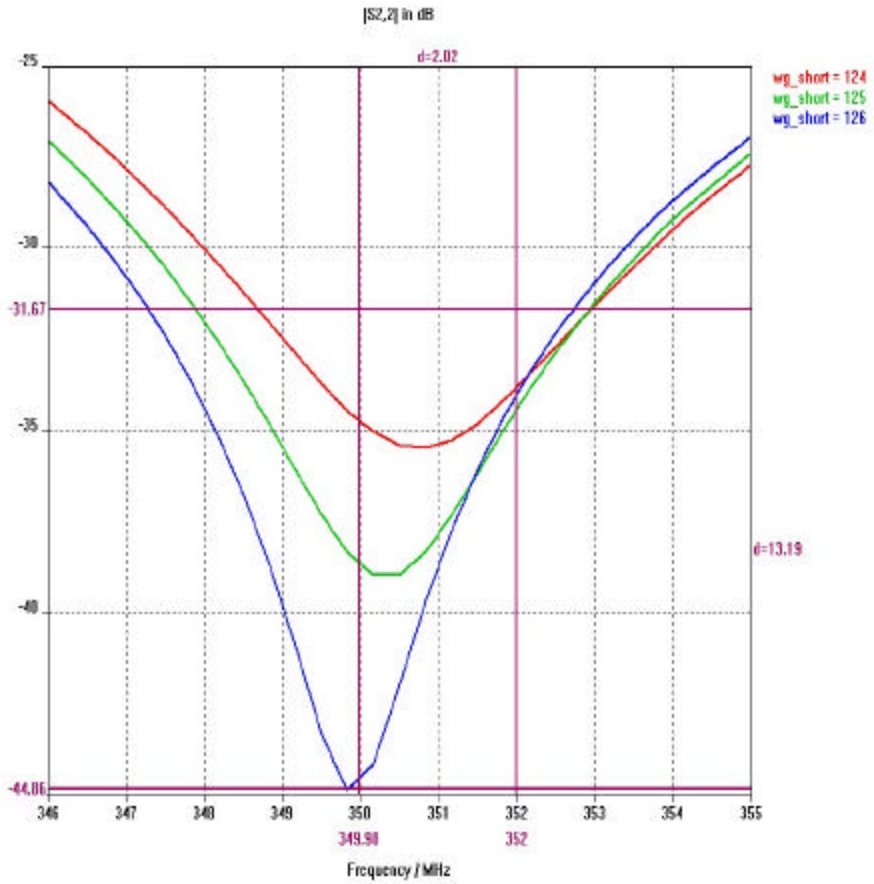
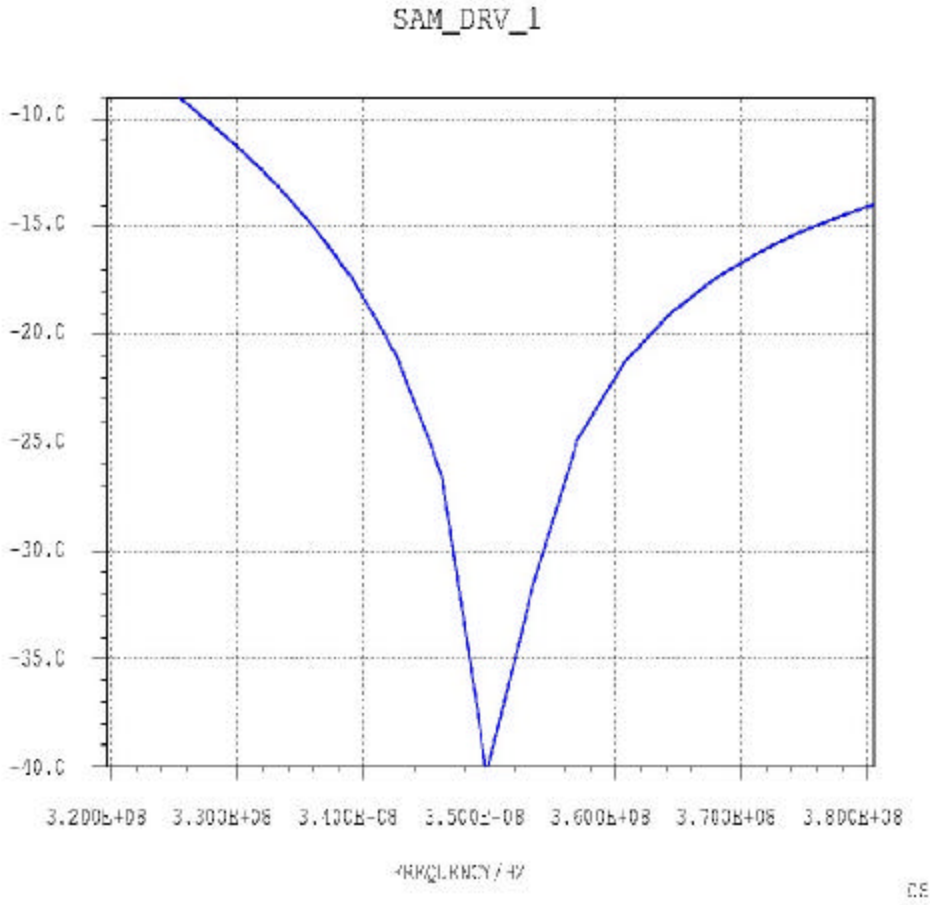




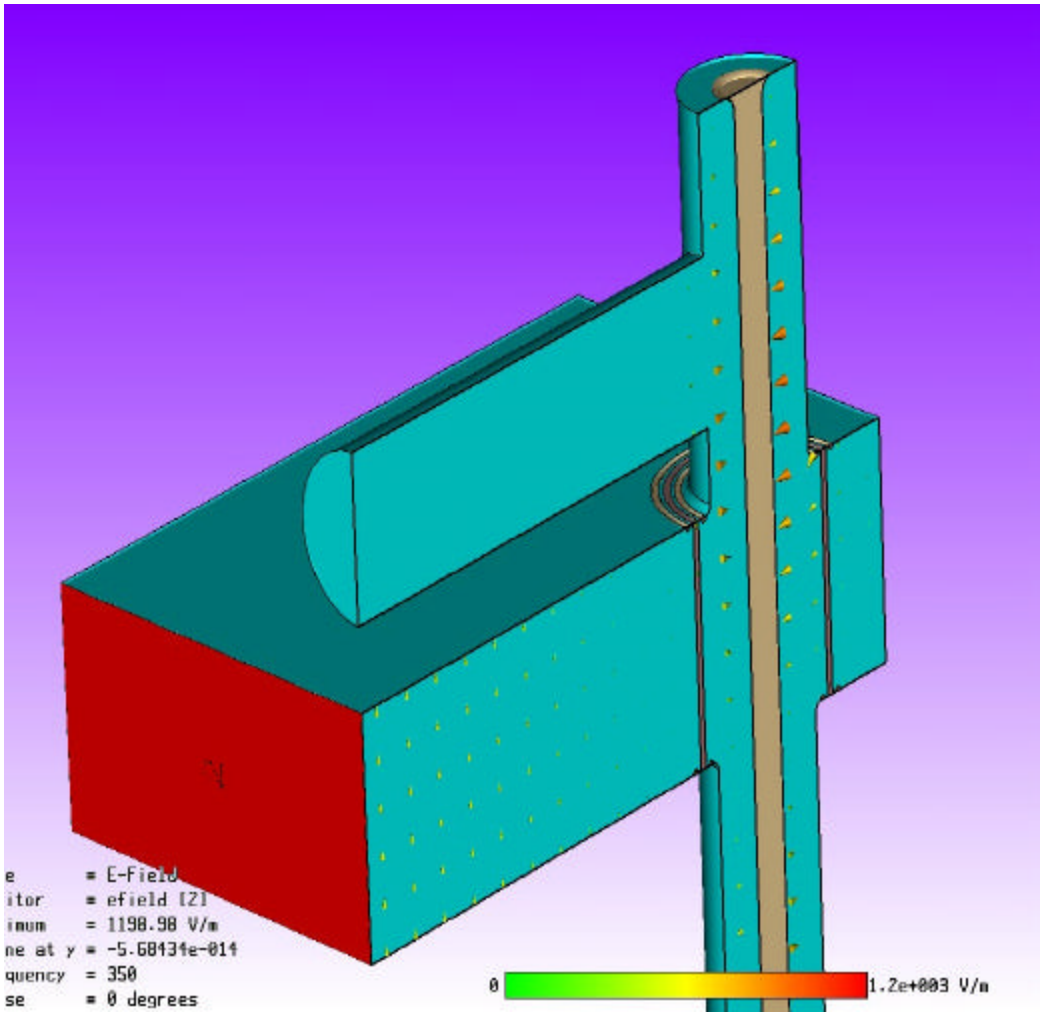
Geometry Data

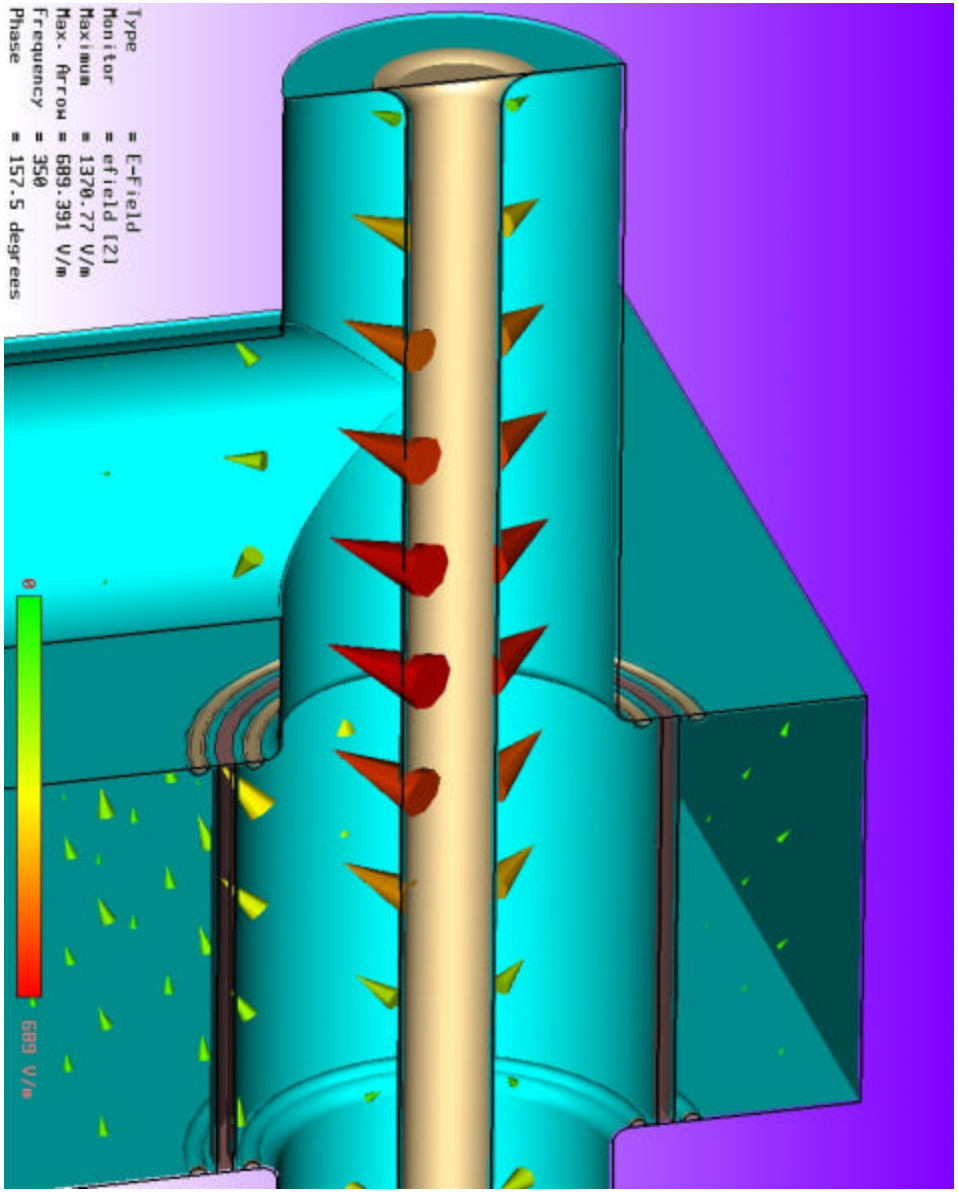
Coax Diameter	103 mm	CERN Dimensions
Coax Impedance	75 W	
Waveguide	WR 2300	
Window Type	Cylinder	
Window Material	95 % Alumina	e = 9.1, tan (d) = 0.0027
Window OD	139 mm	
Window Thickness	5 mm	
Transition		l/4 stub to half-height wg
Coax Short	306 mm	from center of window
Waveguide Short	123.5 mm	from center of window
Vacuum Port	103 mm	in coax stub
V. Port Position	136 mm	Top of wg to center of por
Coax Length	1196 mm	RF-length (short to tip)
Coupler Orientation	45 degrees	Relative to spoke

RF Data

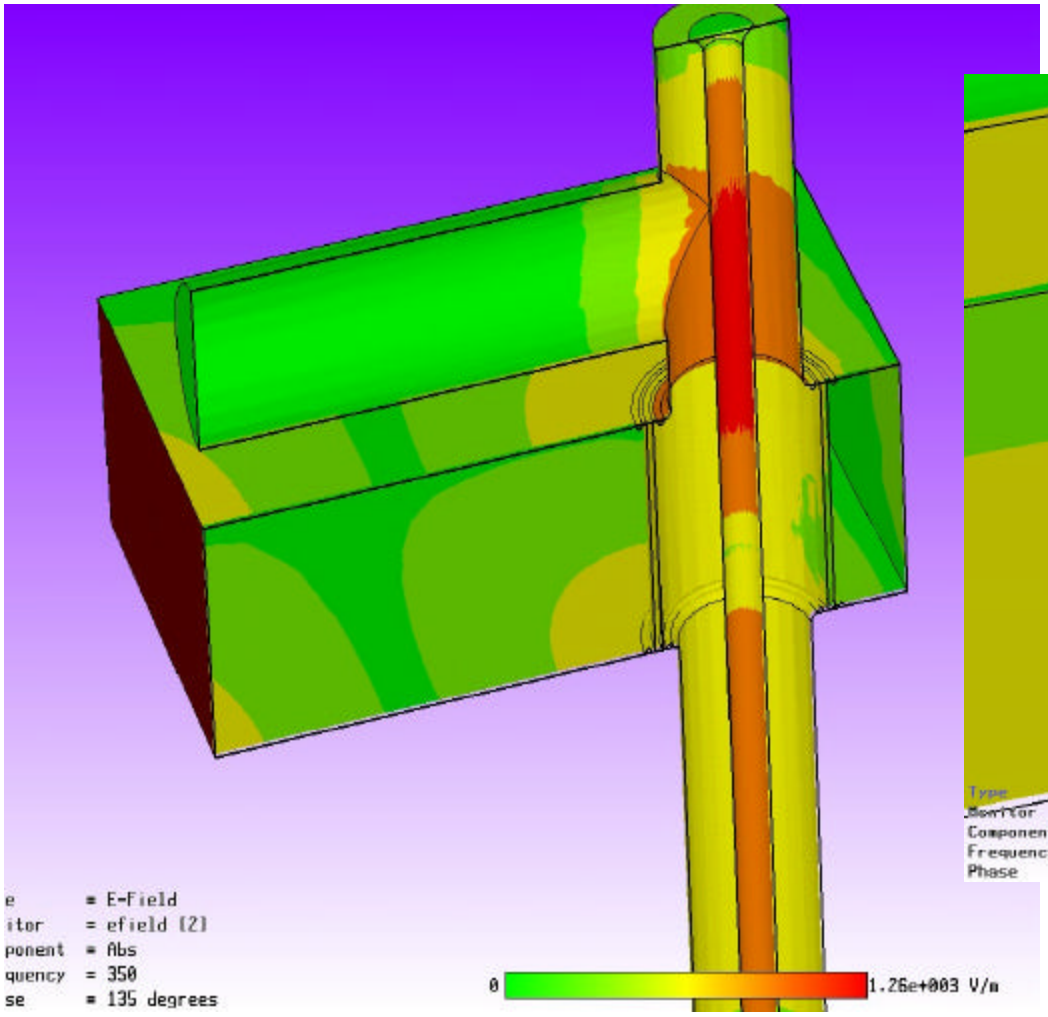
Match Frequency	350 MHz	
Return Loss	< -40 dB	
Bandwidth	> ± 4 MHz	better than -30 dB
Power transmissior	> 99.83 %	w/o copper losses
Power in window	0.17%	
E_{peak}	1.5 kV/m	@ 1 W
Enhancement	2.2	Enhancement in Stub

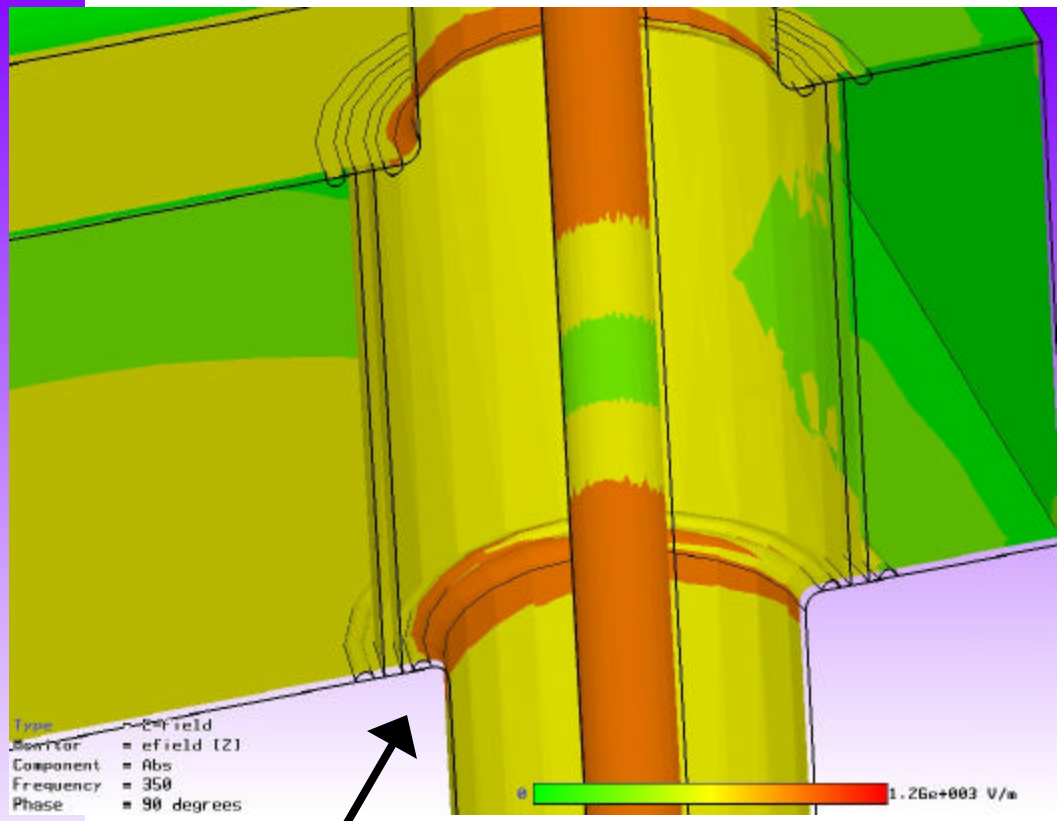
Electric Field





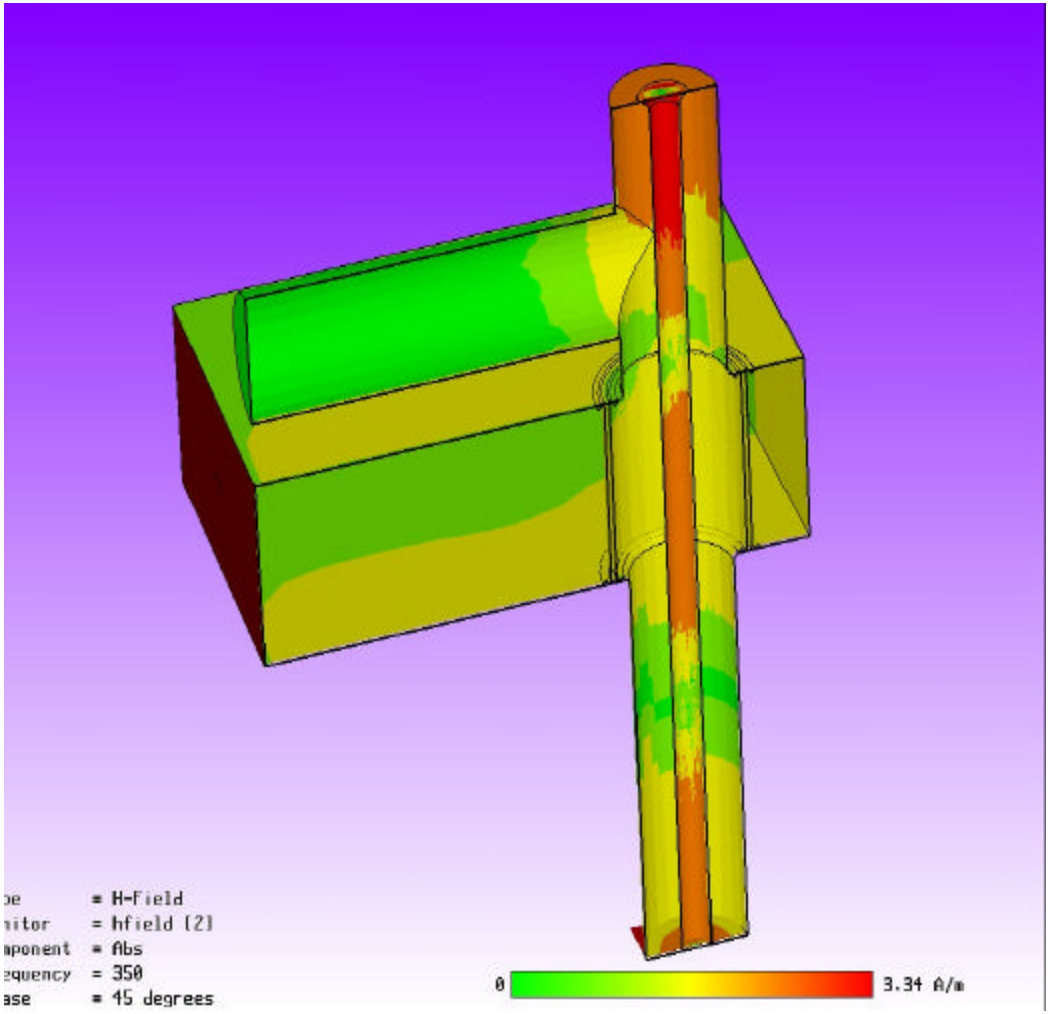
Electric Peak Fields

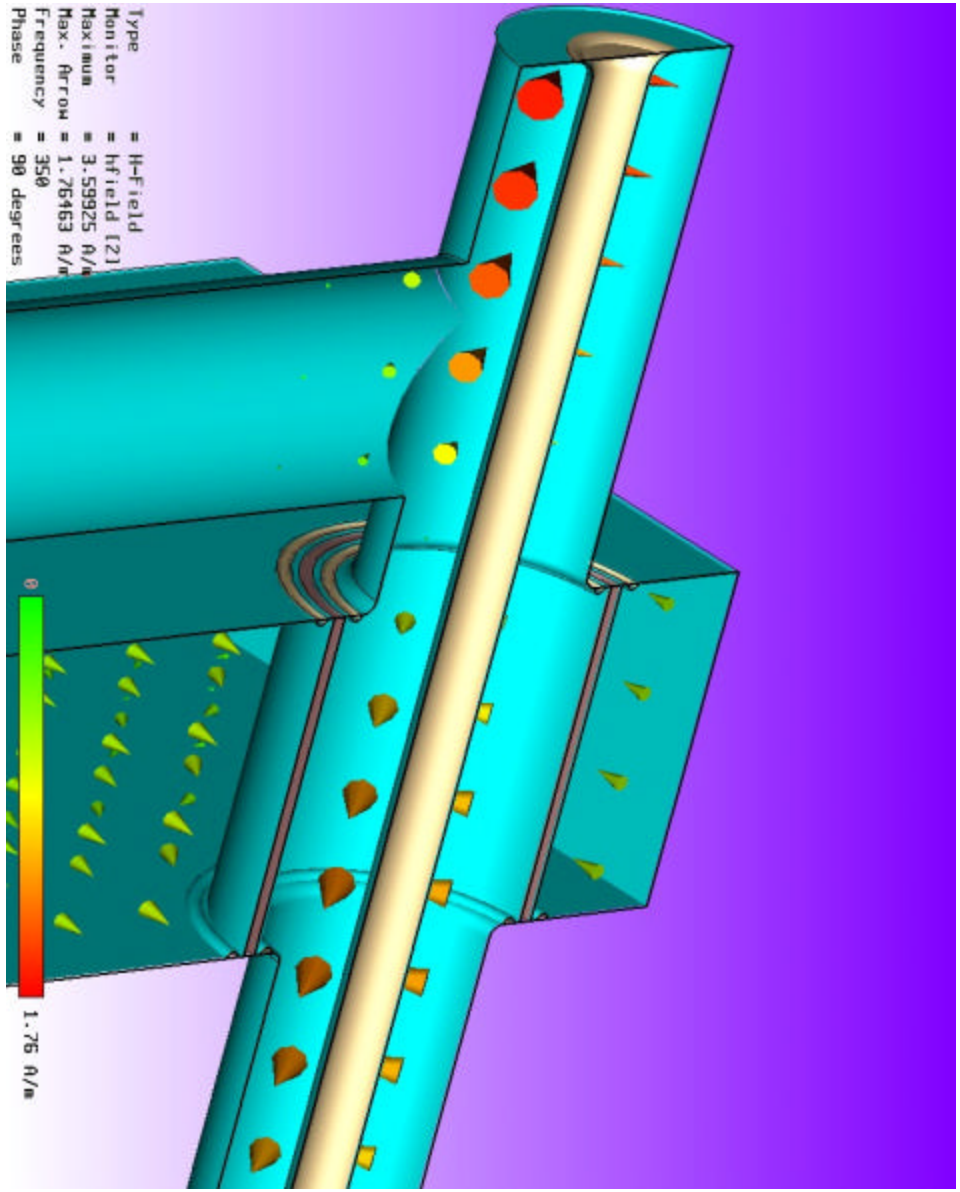




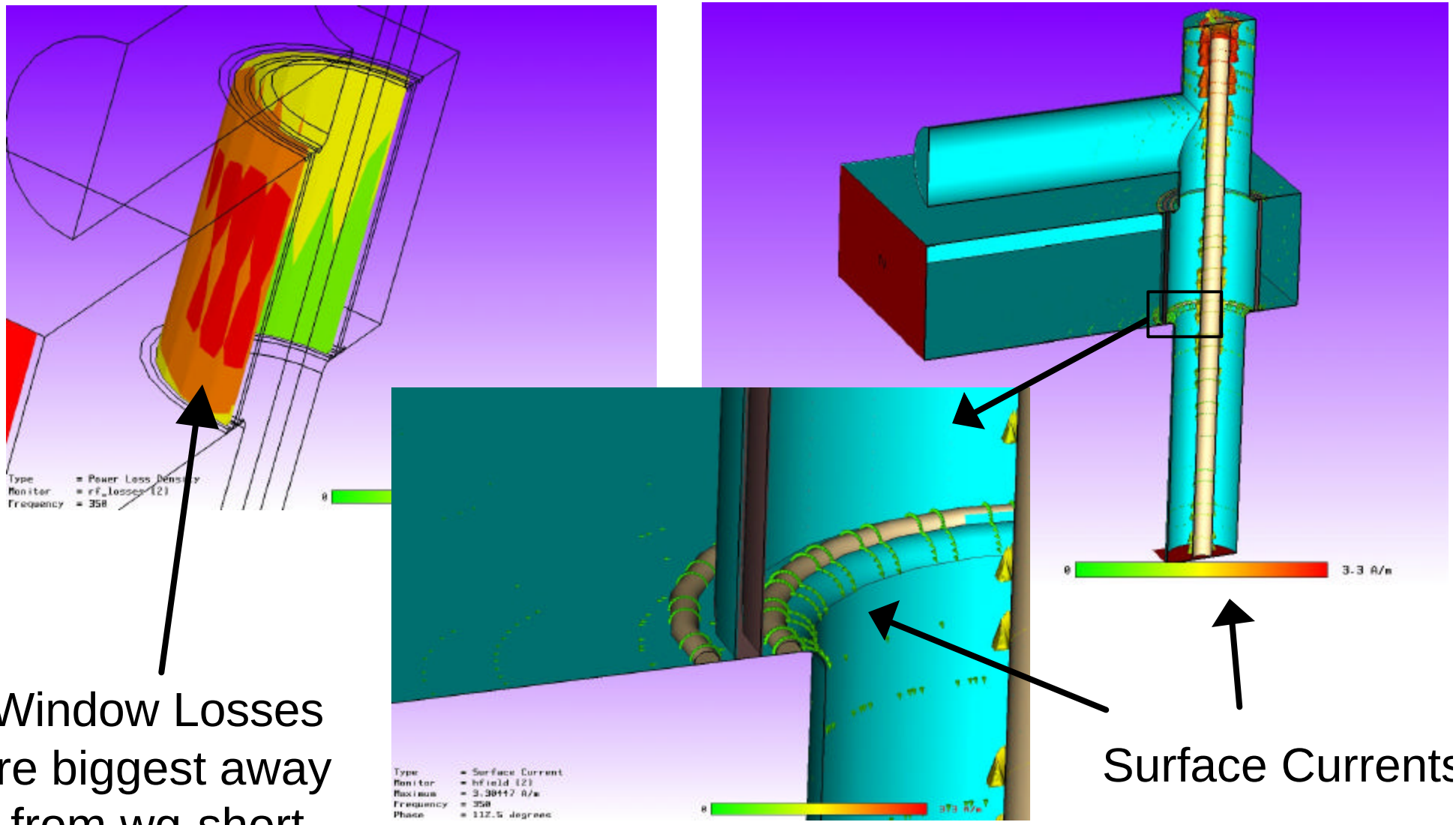
Braze Protection

Magnetic Field





Loss Distribution

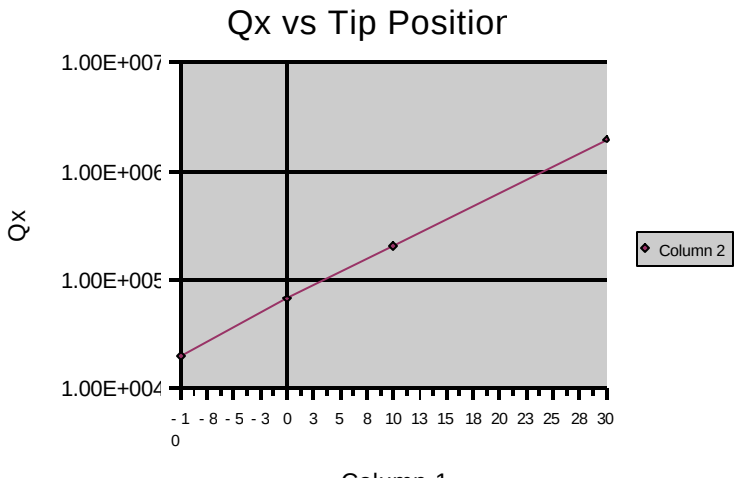


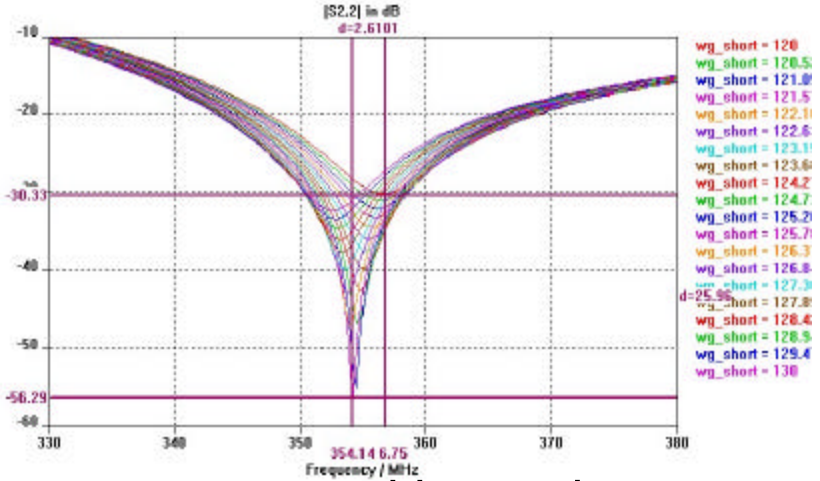
Window Losses are biggest away from wg-short

Surface Currents

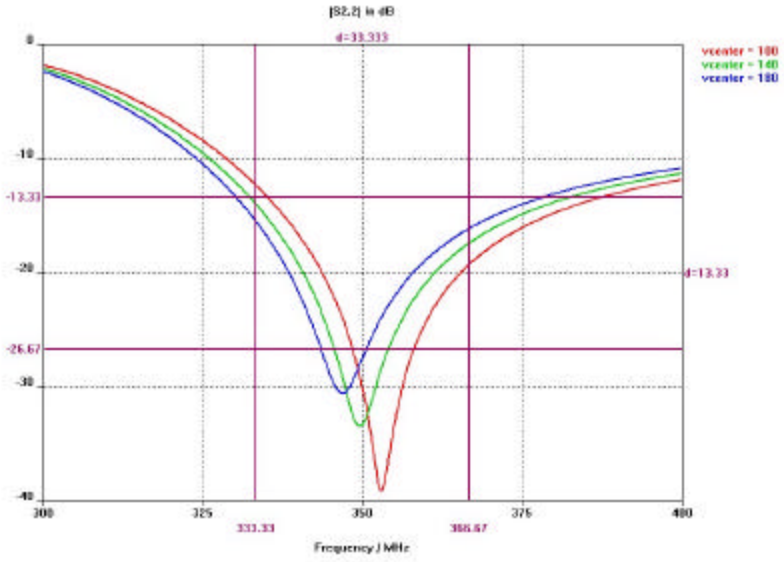
Sensitivities

ΔQ_{ext}

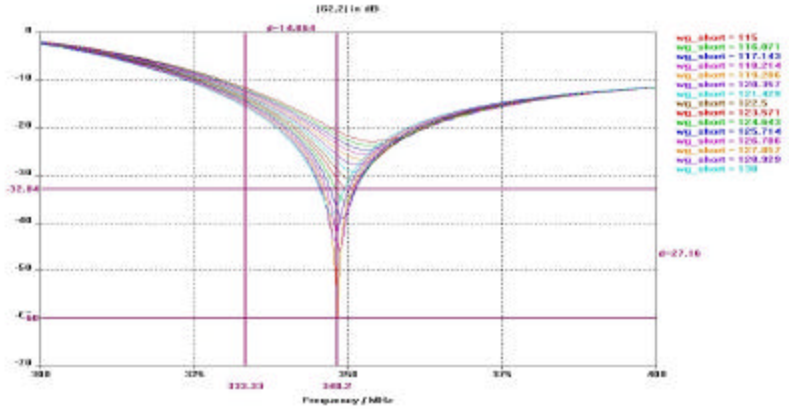




Δ_{match} with wg-short



Δ_{match} with vacuum port



Δ_{match} with coax-short

Sensitivities II

Q_{ext} (100 mA)	1.90E+005	tip @ -7 mm
Q_{ext} (13.3 mA)	1.40E+006	tip @ -20 mm
f_0 (-7 mm)	349.618 MHz	df < 23 kHz
f_0 (-20 mm)	349.595 MHz	5% of range
Coax Short	TBD	Mostly f_{match}
Wg Short	TBD	Mostly return loss

Power Deposition

	APT (700 MHz)		ED&D (350 MHz)		
	100 mm		103 mm		
	W/cm^2	W	W/cm^2	W	
Inner	N/A	N/A	8.24E-007	4.00E-004	@ 1W
Outer	N/A	N/A	6.60E-008	N/A	
Inner	N/A	N/A	7.03E-003	3	@ 8.5 kW
Outer	N/A	N/A	5.60E-004	N/A	
Inner	N/A	N/A	5.30E-002	23	@ 63.6 kW
Outer	N/A	N/A	4.20E-003	N/A	
Inner	1.50E-001	190*	1.75E-001	77	@ 211.8 kW
Outer	3.00E-002	N/A	1.40E-002	N/A	

RF losses in Cu at 350 MHz for a straight coaxial line except *, which takes into account the losses in the stub

Summary

- The basic properties of a high power coupler have been selected:
  - coaxial coupler with a $\lambda/4$ wg to coax transition.
  - electric coupling directly to cavity body.
  - coupling scheme has been verified in the lab.
  - coaxial dimensions selected to avoid mulitpacting at operation power level.
- Based on this a RF design has been done with established 3D simulation codes.
- The basic foot print of the coupler has been established.
- Some sensitivites for fabrication are being established.
- The cavity coupler interaction has been studied.
- The basic Rf losses have been determined as input for a thermal and stress analysis.
- Further optimization will not change the essence of the results obtained to date.